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Surgical decision-making for managing complex intracranial aneurysms

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Abstract: The treatment of complex intracranial aneurysms remains a therapeutic challenge. These lesions are frequently not amenable to selective clipping or coiling or other endovascular procedures and surgery still has a predominant role. We illustrate our "surgical decision making" for managing complex intracranial aneurysmal lesions. The best strategy is decided on the basis of pre-operative neuroradiological and intra-operative main determinants such as anatomical location, peri-aneurysmal angioanatomy (branch vessels, critical perforators), broad neck, intraluminal thrombosis, aneurysmal wall atherosclerotic plaques and calcifications, absence of collateral circulation, and previous treatment. The surgical strategy encompasses one of the following treatment possibilities: (1) Direct clip reconstruction; (2) Complete trapping ("classic" or "variant"); (3) Partial trapping (proximal "inflow" or distal "outflow" occlusion). Because the goal of any aneurysm treatment is both (1) aneurysm exclusion and (2) blood flow replacement, cerebral revascularization represents a major management option whenever definitive or temporary vessel occlusion is needed. Cerebral revascularization can therefore be used temporarily as a "protective" bypass, or definitively as a "flow replacement" bypass. Complete and partial trapping strategies are associated with flow "replacement" bypass surgery, to preserve blood flow into the territory supplied by the permanently trapped vessel. The construction of the "ideal" bypass depends on several factors, the most important of which are amount of flow needed, recipient vessel, donor vessel, and microanastomosis technique. The choice between "complete" or "partial" trapping depends on angioanatomical criteria as well. A complete trapping is always favored, as it has the advantage of immediate aneurysm exclusion. When perforating vessels arise from the aneurysmal segment or when the inspection of all the angioanatomy of the aneurysm is considered inadvisable and risky, "partial trapping" strategies are of interest. Partial trapping may consist either of proximal or distal occlusion. We discuss the rationale behind these treatment modalities and illustrate it with a case series of seven patients successfully treated for complex intracranial aneurysmal lesions (location: 1 ICA, 1 ACom, 3 MCA, 2 PICA).

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ABSTRACT

The treatment of complex intracranial aneurysms still remains a therapeutic challenge. These lesions are frequently not amenable to selective clipping or coiling or other endovascular procedures and surgery still has a predominant role.

We illustrate our "surgical decision making" for managing complex intracranial aneurysmal lesions. The best strategy is decided on the basis of pre-operative neuroradiological and intra-operative main determinants such as: anatomical location, peri-aneurysmal angioanatomy (branch vessels, critical perforators), broad neck, intraluminal thrombosis, aneurysmal wall atherosclerotic plaques and calcifications, absence of collateral circulation, and previous treatment. The surgical strategy encompasses one of the following treatment possibilities: 1) Direct clip reconstruction; 2) Complete trapping ("classic" or "variant"); 3) Partial trapping (proximal "inflow" or distal "outflow" occlusion). Because the goal of any aneurysm treatment is both 1) aneurysm exclusion and 2) blood flow replacement, cerebral revascularization represents a major management option, whenever definitive or temporary vessel occlusion is needed.

Cerebral revascularization can therefore be used temporarily as a “protective” bypass or definitively as a “flow replacement” bypass.
Complete and partial trapping strategies are associated with a flow “replacement” bypass surgery, to preserve blood flow into the territory supplied by the permanently trapped vessel. The construction of the “ideal” bypass depends on several factors, the most important of which are: amount of flow needed, recipient vessel, donor vessel, and microanastomosis technique.
The choice between “complete” or “partial” trapping depends on angioanatomical criteria as well. A complete trapping is always favored, as it has the advantage of immediate aneurysm exclusion. When perforating vessels arise from the aneurysmal segment or when the inspection of all the angioanatomy of the aneurysm is considered inadvisable and risky, “partial trapping” strategies are of interest. Partial trapping may consist either of proximal or distal occlusion. We discuss the rational behind these treatment modalities and illustrate it with a case series of 6 patients successfully treated for complex intracranial aneurysmal lesions (location: 1 ICA, 1 ACom, 3 MCA, 2 PICA).

Abbreviations

ACom: anterior communicating artery; CT: Computed Tomography; CT-A: Computed Tomography angiography; DSA: Digital Subtraction Angiography; EC-IC: extra-to-intracranial; ELANA: Excimer Laser Assisted Non occlusive Anastomosis; IA: intracranial aneurysm; ICA: internal carotid artery; IC-IC: intra-to-intracranial; ICG-VA: Indocyanine Green Video Angiography; MCA: middle cerebral artery; MRI: Magnetic Resonance Angiography; MRI: Magnetic Resonance Imaging; mRS: modified Rankin Scale; PICA: posterior inferior cerebellar artery; STA: superficial temporal artery; STA-MCA: superficial temporal artery to middle cerebral artery

Key words: complex intracranial aneurysms; extra-to-intracranial bypass, giant aneurysms; reconstruction; partial trapping; trapping; trapping variant.

INTRODUCTION

Complex cerebral aneurysms include both giant and large/small aneurysms the complexity of which is due to anatomical location, peri-aneurysmal angioanatomy (branch vessels, critical perforators), broad neck, intraluminal thrombosis, atherosclerotic plaques or calcifications of the aneurysmal wall, absence of collateral circulation, and previous treatment (1, 4, 7, 9). These lesions are frequently not amenable to selective clipping or coiling or other endovascular procedures. Their treatment still remains a therapeutic challenge and surgery still has a predominant role (7). Herein we present our surgical decision making for the treatment of intracranial complex aneurysmal lesions.

MATHERIALS AND METHODS

Pre-op neuroimaging

A comprehensive understanding of the pre-op neuroimaging is mandatory. Pre-operative neuroradiological exams must include a CT angiography (CTA) and/or a digital subtraction angiography (DSA). 3D reconstructions sequences are very important for a detailed angioanatomical evaluation. When bypass surgery represents a possible treatment modality, either a DSA with injection of the external carotid artery or 3D-CTA of scalp vessels (namely the superficial temporal artery – STA - and its branch, as well the occipital artery) is performed.

Intra-operative tools

To assess vessels patency and direction of the flow we use intraoperative Indocyanine green Video angiography (ICG-VA), performed by the use a commercially available surgical microscope (OPMI® Pentero™, The Carl Zeiss Co, Oberkochen, Germany). Real-time ICG-VA images with arterial, capillary, and venous phases can be obtained and analyzed on video screen, as recorded for further analysis too.

Intraoperative flow measurements are performed in all the perianeurysmal branches (feeding artery and branch arising from the aneurysms) with a flowmeter (Transonic Systems Inc., Ithaca, New York). The flow in the bypass is measured as well.

Surgical decision making

A flow chart illustrating the possible strategies for managing complex intracranial aneurysms (IAs) is presented. On the basis of both pre-operative neuroradiological exams and intraoperative findings, one of the following treatment strategies is chosen (see flow chart in Figure 1):

1) Direct vessels reconstruction by clip or other (+ “protective” bypass in case of prolonged temporary occlusion)

2) Complete trapping (+ flow “replacement” revascularization). Two types of complete trapping modalities are described:
    a. complete trapping “classic”: the aneurysm is completely occluded as well as all the branches originating from the aneurysmal segment (the aneurysm and the whole aneurysmal arterial segment are excluded from the circulation = complete trapping).
    b. complete trapping “variant”: the aneurysm is completely occluded with sacrifice of one or more , but not all, of the branches arising from the aneurysmal segment (the aneurysm and some, but not all, the branches arising form the aneurysmal segment are excluded from the circulation = complete trapping “variant”).

3) Partial trapping (+ flow "replacement" revascularization): it consists of either proximal "inflow" or distal "outflow" occlusion. The aneurysm is not completely excluded from the circulation (= partial trapping).

SURGICAL DECISION MAKING FOR THE TREATMENT OF COMPLEX INTRACRANIAL ANEURYSMS

1. **Direct vessels reconstruction (by clip or other) ***
2. **Complete trapping *(+ flow-replacement revascularization*)**
   - **Complete trapping «classic»**
   - **Complete trapping «variant»**
3. **Partial trapping (*+ flow-replacement revascularization*)**
   - **Proximal «inflow» occlusion**
   - **Distal «outflow» occlusion**

***: possibility of protective bypass (in case of prolonged occlusion time needed)**

Figure 1

Flow chart illustrating our strategies for managing complex intracranial aneurysms.

Post-op neuroimaing

Post-operative control angiography (CTA or DSA) is routinely executed in the first 72h after surgery. In case of clip-reconstruction, follow-up neuroradiological exams are performed as for other clipped aneurysm patients. When the aneurysm treatment consists of complete trapping in association with bypass surgery, besides the first CTA in the first 72 h post-op, a further CTA is generally requested at 3 months to study bypass patency. In case of partial trapping, follow-up imaging studies are performed to evaluate aneurysm evolution on the basis of immediate post-op findings.

RESULTS

Illustrative case series

A case series of 6 patients successfully treated for complex intracranial aneurysmal lesions (location: 1 ICA, 1 ACom, 3 MCA, 2 PICA) (Figures 2-7). All the patients underwent successful aneurysms treatment. All the bypasses were patent after surgery and at follow-up. No ischemic complications have been reported. A favorable clinical outcome was achieved in all patients (modified Rankin Scale at follow-up ≤ modified Rankin Scale preoperative).

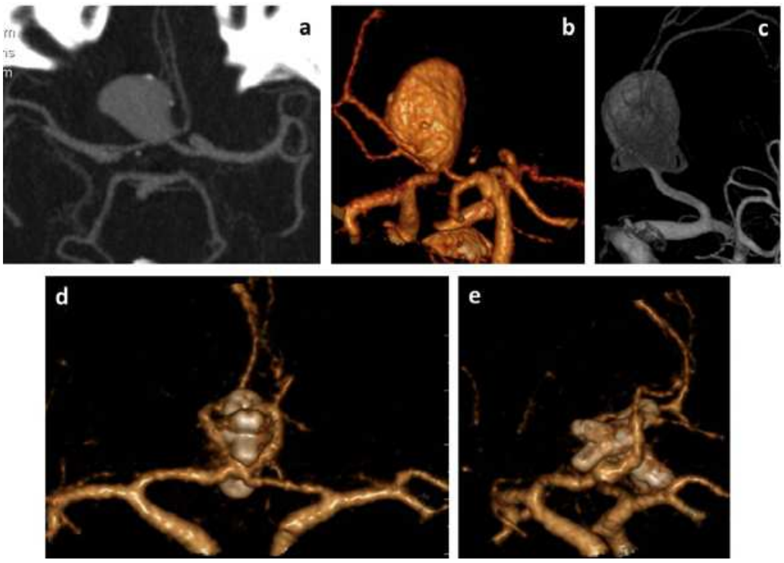

Figure 2: Pre-operative 3D-CTA and 3D-DSA showing a ruptured giant calcified and partially thrombosed ACom aneurysm (WFNS 2) (figures a-c). Treatment consisted of thrombectomy, endarteriectomy and clip reconstruction. 3D-CTA performed 72 h after surgery documented aneurysm exclusion and patency of all the ACom complex arteries (figures d-e).

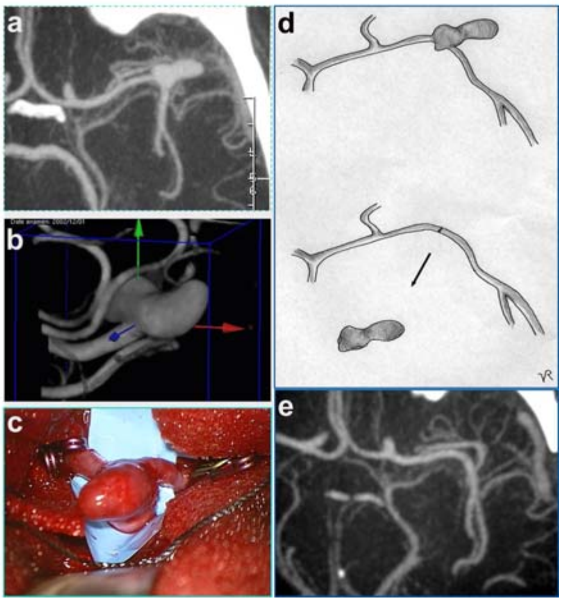

Figure 3: Direct vessels Reconstruction. Pre-operative axial CTA and 3D-DSA showing a complex ruptured aneurysm of the left MCA (WFNS 1) (figures a-b). Intraoperatively, after aneurysm dissection (figure c), direct vessels reconstruction was considered feasible. So the aneurysm was excised and an “end-to-end” anastomosis between the two MCA stumps was performed (figure d). Post-operative CTA showed excellent results with aneurysm disappearance and the patency of the anastomosis (figure e).

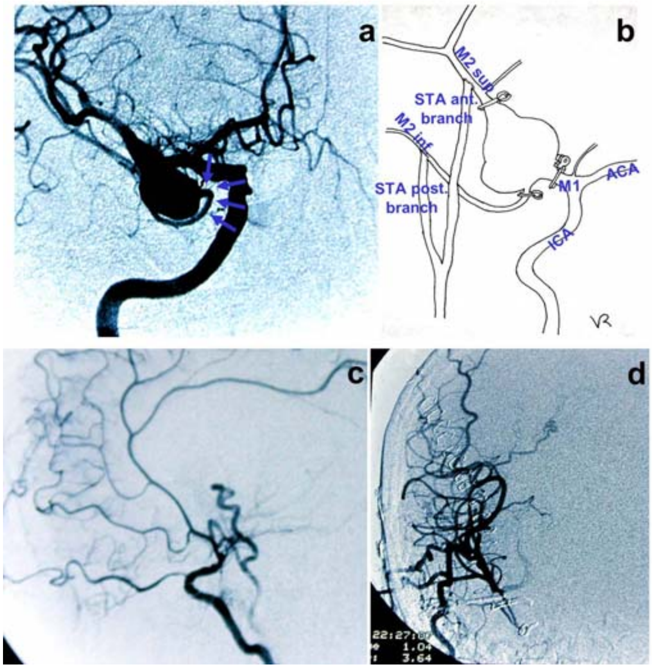

Figure 4: Complete trapping (classic) + EC-IC bypass. Preoperative DSA showing a complex unruptured MCA aneurysm (figure a). The aneurysmal lesion was treated by complete trapping and double STA-MCA (figure b). Post-operative DSA showed aneurysm disappearance and patency of the bypasses.

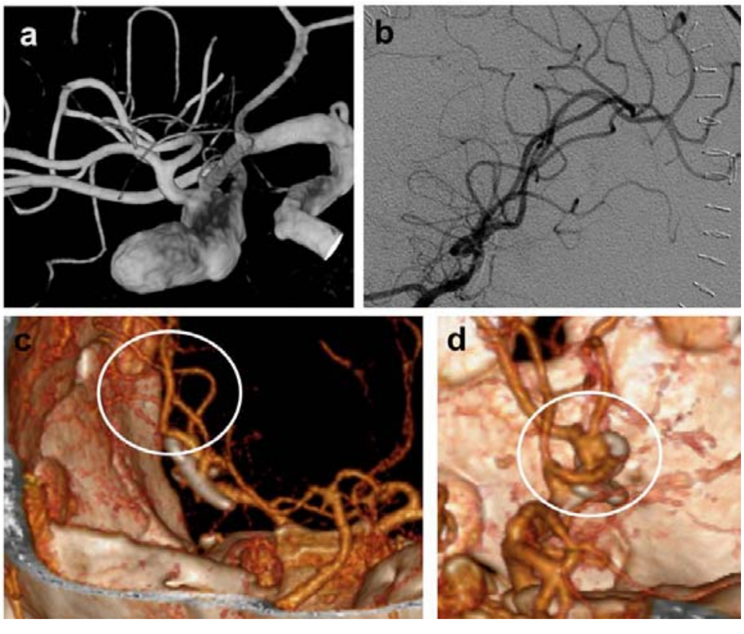

Figure 5: Complete trapping "variant" + flow-replacement IC-IC bypass. A complex unruptured MCA bifurcation aneurysms (partially thrombotic and calcified) (pre-op DSA in figure a) has been treated by aneurysm clipping with sacrifice of the frontal M2 branch, that was previously revascularized by means of intracranial-intracranial M3-M3 side-to-side anastomosis. Postoperative DSA and 3D-CTA showed aneurysm exclusion and patency of the anastomosis (figures b-d).

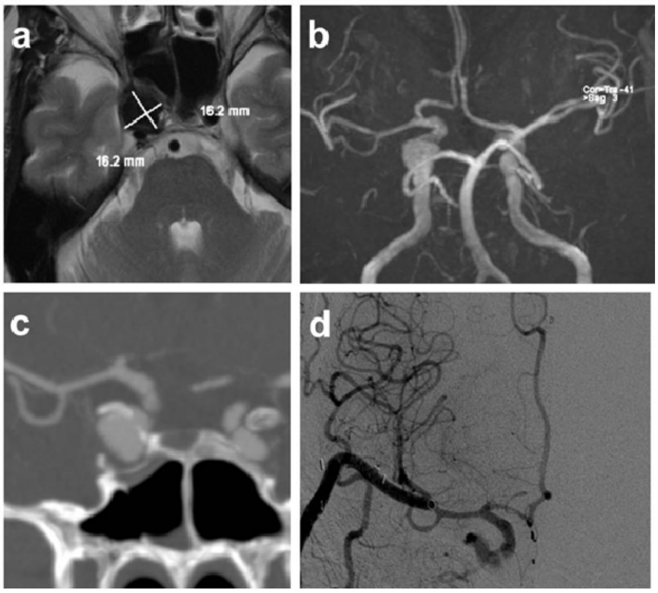

Figure 6: Partial trapping (inflow occlusion) with EC-IC (Elana) bypass. Pre-operative axial MRI (a), MRA (b) and CTA (c) showing an aneurysm of the right intracavernous ICA. The patient underwent treatment consisting of: 1) EC-IC high flow bypass performed by interposition of a saphenous vein graft between the external carotid artery and the MCA (M2 segment); 2) subsequent proximal occlusion of the cervical internal carotid artery in the neck just distal to the common carotid artery bifurcation. Postoperative DSA (figure d) showed patency of the EC-IC bypass and partial aneurysmal thrombosis. Note that the intracranial anastomosis has been made by the application of the Excimer- Laser Assisted Non Occlusive Anastomosis (ELANA) technique, in order to avoid temporary occlusion of a proximal intracranial recipient (namely the supraclinoidal ICA or the MCA) and subsequent risk of cerebral ischemia.

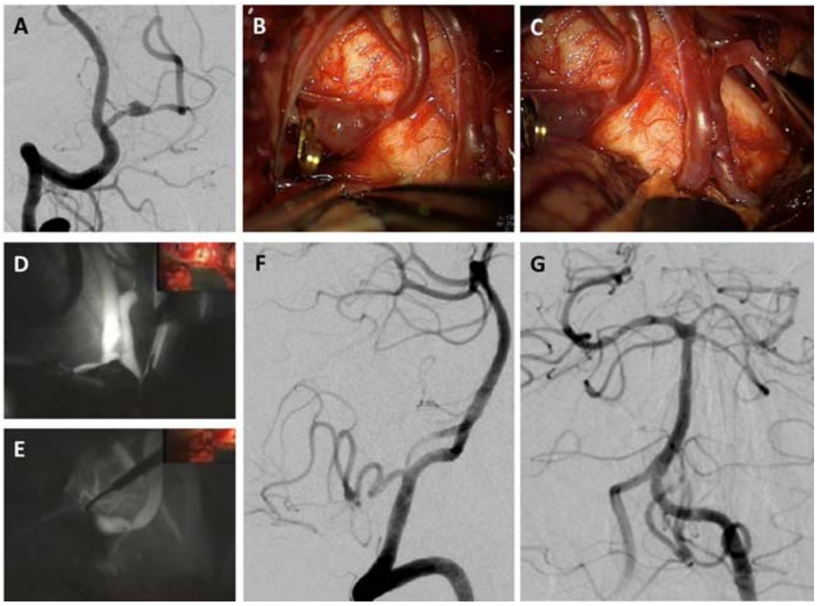

Figure 7: Partial trapping (inflow occlusion) with IC-IC bypass. Preoperative DSA showing a dissecting ruptured posterior inferior cerebellar artery (PICA) aneurysm (WFNS 1) (figure A). Intraoperatively the aneurysm was treated by means of side-to-side PICA-PICA anastomosis and proximal (inflow) occlusion (figures B and C). Intraoperative Indocyanine green videoangiography showing the patency of the side-to-side anastomosis (figure D) and the absence of fluorescence in the aneurysm (figure E). Postoperative DSA confirming patency of the anastomosis and documenting disappearance of the aneurysmal lesion (figures f-g)

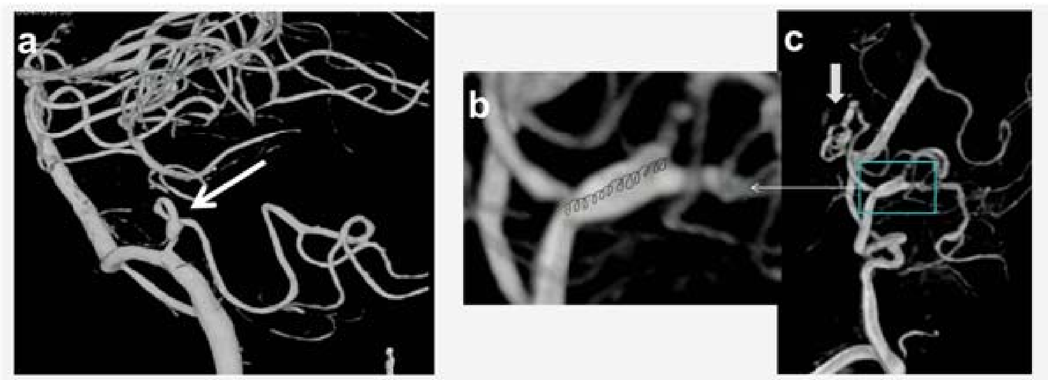

Figure 8: Partial trapping (outflow occlusion) + IC-IC bypass. Preoperative 3D-DSA showing a dissecting unruptured aneurysm of the posterior inferior cerebellar artery (PICA) (figure a). The aneurysms was treated by side-to-side PICA-PICA bypass and subsequent distal outflow occlusion. Postoperative DSA showed aneurysm disappearance and patency of the side-to-side anastomosis (figures b, c).

Discussion

The surgical strategy for complex aneurysms is decided on the basis of pre-op neuroradiological and intra-op main determinants such as: anatomical location, peri-aneurysmal angioanatomy (branch vessels, critical perforators), broad neck, intraluminal thrombosis, aneurysmal wall atherosclerotic plaques and calcifications, absence of collateral circulation, previous treatment (2, 7). Obviously, because the goal of any aneurysm treatment is both aneurysm exclusion and blood flow preservation (2-3), when vessels sacrifice or prolonged temporary occlusion are needed, cerebral revascularization is an important management option (2, 4, 7-9). The selection of the ideal bypass procedure (EC-*IC vs.* IC-IC; occlusive *vs.* non-occlusive, etc.) depends on several factors, for instances the amount of flow to the occluded (temporary or permanently) arterial territory, the intracranial vascular angioarchitecture, the availability of donor and recipient vessels, etc (1-3, 7).

Reconstruction of complex aneurysms by clips can be possible, for instances after thrombectomy/endarteriectomy in case of giant partially thrombosed aneurysm (Figure 2). Sometimes even direct vessel reconstruction is a valid option, depending on favorable aneurysmal angioanatomy (Figure 3). These treatment modalities can be associated with a “protective” bypass, when prolonged temporary occlusion time is needed (9).

Trapping strategies are instead combined with the construction of flow a replacement bypass. The choice of “complete” or “partial” trapping depends on the aneurysmal and peri-aneurysmal anatomy.

The advantage of “complete trapping” is the immediate exclusion of the aneurysmal lesions and is the recommended option when ever feasible (3-5). Two types of “complete trapping” strategies are herein described, the “classic” and the “variant” trapping. A “classic” complete trapping consists of exclusion of the aneurysm as well as the total corresponding arterial territory. Bypass surgery needs to revascularize the whole territory supplied by the artery carrying the aneurysm (figure 4). The “variant” trapping consists of complete aneurysm exclusion, with occlusion of one or more, but not all, branches arising from that segment. Bypass surgery needs to revascularize only a part of the territory supplied by the artery carrying the aneurysm (figure 5).

However, complete trapping can be sometime hazardous, for instances when perforating vessels arise from the aneurysm sac, or when careful inspection of every aspect of the aneurysms is considered inadvisable and risky. In these cases, partial trapping strategies represent a reasonable option, (2, 4-6, 9-10). Two types of partial trapping modalities are described: proximal “inflow” occlusion (figure 6-7) and distal “outflow” occlusion (figure 8), consisting of respectively occlusion before or after the aneurysmal lesion (3-7, 9-10). A bypass is associated to ensure perfusion to the territory distally to the occlusion. The rational behind inflow and outflow occlusion is the change of flow within the aneurysmal lesion, inducing a reduction of blood flow and a decrease in hemodynamic stress. A major limitation of the partial trapping strategy remains however our incapacity to reliably predict as well as to control the amount and the speed of the thrombosis of the aneurysm. Rapid and complete thrombosis of a giant aneurysm may carry the risk of either aneurysm rupture or occlusion of the perforating arteries that one tried to preserve using partial trapping.

Conclusions

Different treatment modalities for managing complex intracranial aneurysmal lesions have been herein presented. Neurosurgical reference centers for cerebrovascular have to be capable of offering the full spectrum of microsurgical treatment options, including revascularization procedures.

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Disclosure

The authors report no personal financial or institutional interest in any of the drugs, materials, or devices mentioned in this article.